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Creosote Extraction System Performance Evaluation

McCormick & Baxter Creosoting Company

Prepared for

Oregon Department of Environmental Quality
Environmental Cleanup Division
811 S.W. Sixth Avenue
Portland, Oregon 97204

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ABBREVIATIONS AND ACRONYMS

cSt	centistoke
DNAPL	dense nonaqueous-phase liquid
FWDA	former waste disposal area
gpd	gal per day
gpm	gal per minute
LNAPL	light nonaqueous-phase liquid
McCormick & Baxter	McCormick & Baxter Creosoting Company
NAPL	nonaqueous-phase liquid
PTI	PTI Environmental Services
RI/FS	remedial investigation and feasibility study
TFA	tank farm area

1.0 INTRODUCTION

This report presents the results of a performance evaluation of wells in the creosote extraction system at the McCormick & Baxter Creosoting Company (McCormick & Baxter) site. Tests were conducted by PTI Environmental Services (PTI) in the field between March 9 and April 2, 1993 and included dual pumping and total fluids recovery tests as outlined in the statement of work contained in Task Order Amendment No. 2 (PTI 1993). Results of the testing provided site information that was used to develop specific recommendations for expanding the existing extraction system.

The report includes a summary of historical data, field testing results, and recommendations for optimizing the existing system. Recommendations include the addition of several extraction wells, interceptor trenches at the beach, and suggestions for enhanced extraction techniques. The report is organized into four sections which include 1.0, *Introduction*; 2.0, *Performance Evaluation Results*; 3.0, *Summary and Recommendations*; and 4.0, *References*.

Interim remedial actions for creosote extraction at the McCormick & Baxter site were developed during the remedial investigation and feasibility study (RI/FS) process to allow direct extraction of substantial amounts of nonaqueous-phase liquid (NAPL) that had accumulated in site wells. Development of the creosote extraction program is documented in several reports, including the *Draft Interim Remedial Action Work Plan* (PTI 1991a), *Preliminary Conceptual Design Report* (PTI 1991b), *Interim Remedial Action Summary* (PTI 1991c), *Creosote Recovery Work Plan* (PTI 1991d), *Draft Pilot Extraction Testing Results* (PTI 1992a), and *DNAPL Extraction Design Report* (PTI 1992b).

1.1 OBJECTIVES

The purpose for conducting the performance evaluation was to document results of the existing extraction efforts and determine whether this existing system could be expanded with additional extraction wells or trenches. A second objective included determining whether either light nonaqueous-phase liquid (LNAPL) or dense nonaqueous-phase liquid (DNAPL) yields could be increased with enhanced extraction techniques such as dual pumping or total fluids extraction. In addition, LNAPL in well EW-10s was discovered very recently; this well was monitored to assess whether the LNAPL was affected by river stage and tides and to determine the potential for direct LNAPL extraction.

2.0 PERFORMANCE EVALUATION RESULTS

Performance evaluation results are presented in four sections. Section 2.1 describes the characteristics of the current NAPL extraction system; the presence, thickness, physical properties, and sustainable yields of LNAPL and DNAPL by direct extraction are summarized. Section 2.2 provides a summary of tests conducted in the field program. Section 2.3 summarizes the enhanced extraction results for the former waste disposal area (FWDA) and tank farm area (TFA), and Section 2.4 presents a summary of analytical results from the enhanced extraction testing.

2.1 SITE SETTING AND NAPL EXTRACTION SYSTEM

Site investigation and interim remedial action efforts to date have resulted in the installation of 31 monitoring and extraction wells that were screened in soils that contained visible NAPL. Each of these wells is a potential target for NAPL extraction and 22 of them are in locations that allow them to be purged with the existing extraction system. Table 1 provides well construction details. Well locations and lateral extent of visible NAPL contamination, both on land and offshore are shown on Figure 1. Visible contamination is defined as oil staining in the soil, which can range from full saturation of the pore space to a few visible "blebs" of oil scattered in the sandy matrix. This visibly contaminated area covers approximately 20 acres, with 3 acres located onshore in the FWDA and 7 acres onshore in the TFA.

Historical data were compiled to assess the nature of NAPL in the wells used in the extraction program. The data were derived from several historical sources that include the following:

- Weekly purging of five extraction wells conducted by McCormick & Baxter (1989 through September 1991)
- Pilot testing of remedial investigation monitoring wells conducted by PTI (October 1991 through January 1993)
- Full-scale extraction operations conducted by PTI (February 1993 through mid-March 1993).

A summary of the maximum recorded thickness of both LNAPL and DNAPL in each of the wells is presented in Table 2. The maximum NAPL thickness and soil interval that contains visible NAPL are shown in Figures 2 and ? ;r the TFA and FWDA, respectively.

TABLE 1. WELL CONSTRUCTION SUMMARY

Well Number	Installation Date	Well Material	Casing Inside Diameter (in.)	Well Depth[a] (ft)	Screen Length (ft)	Screen Size (in.)	Sump Length (ft)	Screened Interval Below Surface (ft)		Contamination Interval Below Surface (ft)[b]	
								Top	Bottom	Top	Bottom
Tank Farm Area											
MW-Is	7/84	Steel	2	34.38	20.0	0.02	2.00	12.39	32.39	0.0	34.0
MW-Ps	8/84	Steel	4	33.76	10.0	0.01	2.00	21.14	31.14	--	--
MW-7s	11/15-90	SS 304	2	38.52	20.0	0.02	1.00	16.35	36.35	23.0	42.0
MW-8i	1/21/91	SS 304	2	63.84	20.0	0.02	1.00	41.93	61.93	23.0	65.5
MW-26s	7/18/91	SS 304	2	22.31	10.0	0.02	0.25	7.74	17.74	6.0	19.6
MW-27s	7/19/91	SS 304	2	17.20	10.0	0.02	0.25	2.53	12.53	1.5	17.4
MW-28s	7/22/91	SS 304	2	18.03	10.0	0.02	0.25	3.1	13.10	6.0	13.0
MW-29s	7/23/91	SS 304	2	20.20	10.0	0.02	0.25	6.16	16.16	3.0	31.0
MW-30s	7/24/91	SS 304	2	25.22	10.0	0.02	0.25	9.65	19.65	4.5	30.5
EW-1s	10/87	Steel/SS 304[c]	8	43.01	25.0	0.02	0.00	15.00	40.00	NA	NA
EW-4s	8/12/92	SS	4	39.59	10.0	0.02	2.00	25.00	35.00	5.0	34.5
EW-5s	8/14/92	SS	4	39.58	10.0	0.02	2.00	25.68	35.68	16.0	39.5
EW-7s	8/28/92	SS	4	39.71	10.0	0.02	2.00	25.00	35.00	15.5	36.5
EW-8s	9/1/92	SS	4	52.00	20.0	0.02	2.00	28.00	48.00	30.0	55.5
Former Waste Disposal Area											
MW-Ds	9/28/83	PVC (Sch. 40)	2	34.00	5.0	0.02	0.00	28.43	33.43	18.0	32.0
MW-Es	7/84	Steel	2	41.20	20.0	FF	2.00	17.72	37.72	2.0	39.0
MW-Fs	7/84	Steel	2	40.42	20.0	FF	2.00	17.71	37.71	23.5	33.0
MW-Gs	7/84	Steel	2	40.75	20.0	FF	2.00	37.84	2.00	16.5	39.5
MW-18s	11/10/90	SS 304	2	46.00	20.0	0.02	1.00	23.95	43.95	38.0	43.0
MW-20i	1/03/91	SS 304	2	70.90	20.0	0.02	1.00	49.66	69.66	21.0	86.0
MW-21s	1/19/91	SS 304	4	42.80	10.0	0.02	1.00	30.19	40.19	1.5	47.0
MW-25s	5/14/91	SS 304	2	27.12	10.0	0.02	0.25	10.66	20.66	10.5	19.5

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TABLE 1. (cont.)

Well Number	Installation Date	Well Material	Casing Inside Diameter (in.)	Well Depth[a] (ft)	Screen Length (ft)	Screen Size (in.)	Sump Length (ft)	Screened Interval Below Surface (ft)		Contamination Interval Below Surface (ft)[b]	
								Top	Bottom	Top	Bottom
MW-31s	7/29/91	SS 304	2	24.3	10.0	0.02	0.25	9.42	19.42	7.5	26.3
EW-2s	10/87	Steel/SS 304[c]	8	42.93	25.0	0.02	0.00	15.00	40.00	0.0	31.0[d]
EW-3s	7/30/92	SS	4	48.64	20.0	0.02	2.00	25.00	45.00	5.0	50.0
EW-6s	8/17/92	SS	4	44.45	20.0	0.02	2.00	20.00	40.00	20.0	41.5
EW-9s	9/4/92	SS	4	46.50	10.0	0.02	2.00	32.00	42.00	33.0	53.0
EW-10s	9/23/92	SS	4	39.96	20.0	0.02	2.00	15.00	35.00	15.0	35.0
Other Areas											
MW-10s	2/12/91	SS 304	2	35.10	20.0	0.02	1.00	14.60	34.60	1.0	41.7
MW-19s	11/12/90	SS 304	2	34.02	20.0	0.02	1.00	12.08	32.08	28.0	32.0
MW-22i	7/10/91	SS 304	4	52.32	10.0	0.02	0.3	42.5	52.5	32.0	56.0

Note: FF - galvanized steel casing, wrapped with polypropylene filter fabric.
NA - not available

[a] From top of casing.

[b] Soil interval with visible contamination based on sheen and/or NAPL.

[c] Blank well casing is steel, screen is 304 stainless-steel wire wrap.

[d] Depth based on adjacent borehole for MW-23d.

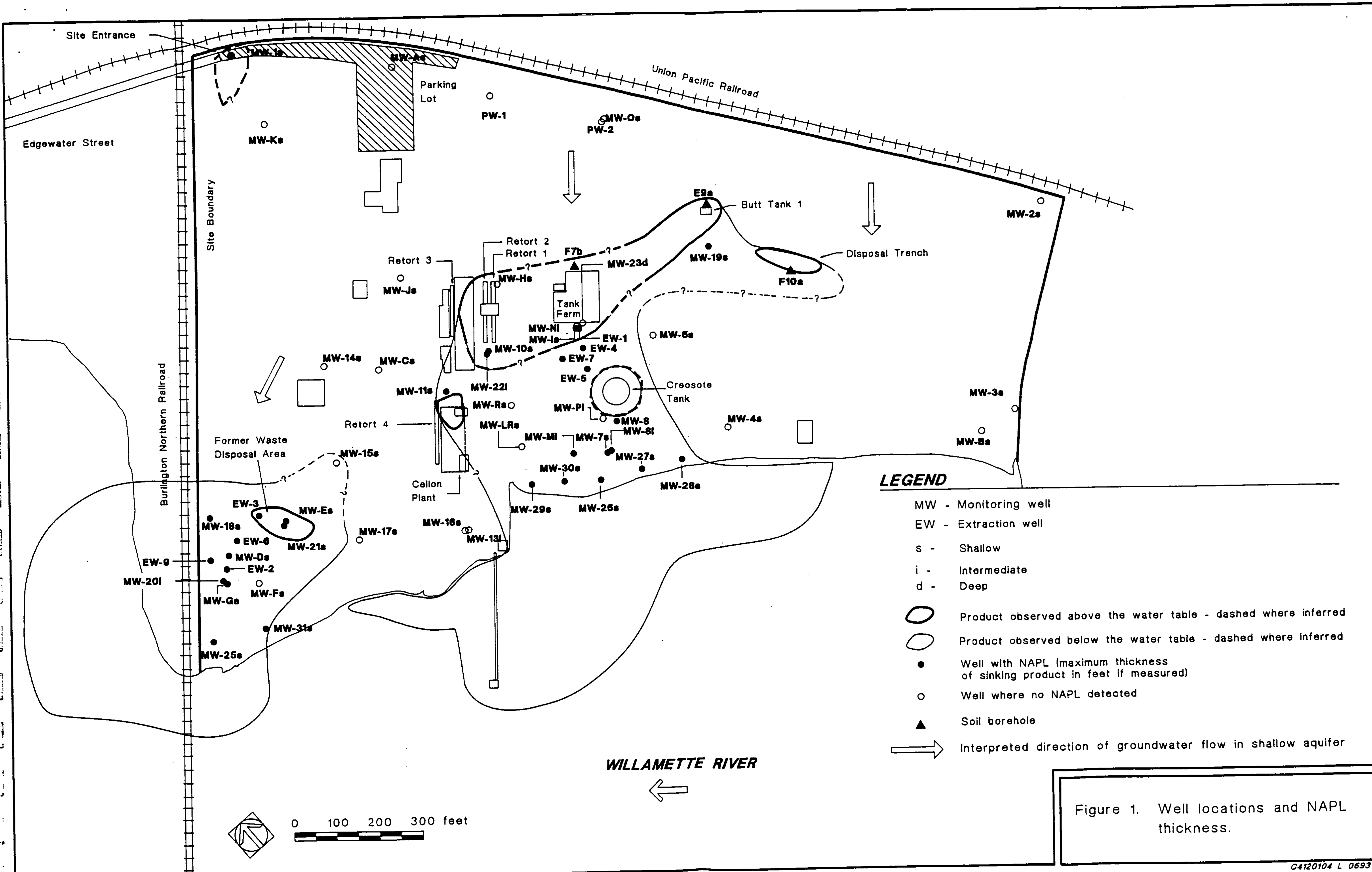

Figure 1. Well locations and NAPL thickness.

TABLE 2. NAPL THICKNESS SUMMARY

Well Number	Installation Date	DNAPL Maximum Thickness (ft)	Date	LNAPL Maximum Thickness (ft)	Date	Period of Time NAPL Observed	Total Gallons Extracted Through 04/10/93
Tank Farm Area							
MW-Is	7/84	9.93	8/87	NM	--	1987-1993	252.9
MW-Ps	8/84	NM	--	NM	--	--	0.0
MW-7s	11/90	3.67	3/91	2.76	9/92	1991-1993	4.0
MW-8i	1/91	1.78	11/91	NM	--	1991-1993	0.3
EW-1s	10/87	1.75	7/92	NM	--	1991-1993	205.0
EW-4s	8/92	3.12	12/92	1.50	9/92	1992-1993	20.0
EW-5s	8/92	NM	--	0.15	12/91	1992-1993	10.0
EW-7s	8/92	0.56	12/92	1.40	9/92	1992-1993	1.3
EW-8s	9/92	1.65	12/92	NM	--	1992-1993	1.3
Former Waste Disposal Area							
MW-Ds	9/83	5.25	8/87	NM	--	1983-1993	120.4
MW-Es	7/84	4.20	8/87	2.97	9/92	1984-1992	0.0
MW-Gs	7/84	14.85	3/91	2.34	9/92	1984-1993	158.1
MW-18s	11/90	NM	--	NM	--	--	0.0
MW-20i	1/91	20.67	10/91	NM	--	1991-1993	316.7
MW-21s	1/91	NM	--	12.30	12/91	1992-1993	33.1
EW-2s	10/87	1.86	8/91	NM	--	1991-1993	56.6
EW-3s	7/92	NM	--	NM	--	--	1.0
EW-6s	8/92	0.10	12/92	NM	--	--	1.0
EW-9s	9/92	2.08	12/92	NM	--	1992-1993	2.4
EW-10s	9/92	NM	--	4.50	12/92	1992-1993	0.3
Other Areas							
MW-10s	2/91	NM	--	8.08	2/93	1992-1993	5.0
MW-19s	11/90	2.01	7/91	NM	--	1991-1993	1.0
MW-22i	1/91	0.66	2/93	--	12/91	1992-1993	1.0

Note: -- not applicable
DNAPL – dense nonaqueous-phase liquid
LNAPL – light nonaqueous-phase liquid
NAPL – nonaqueous-phase liquid
NM – NAPL accumulation not measurable

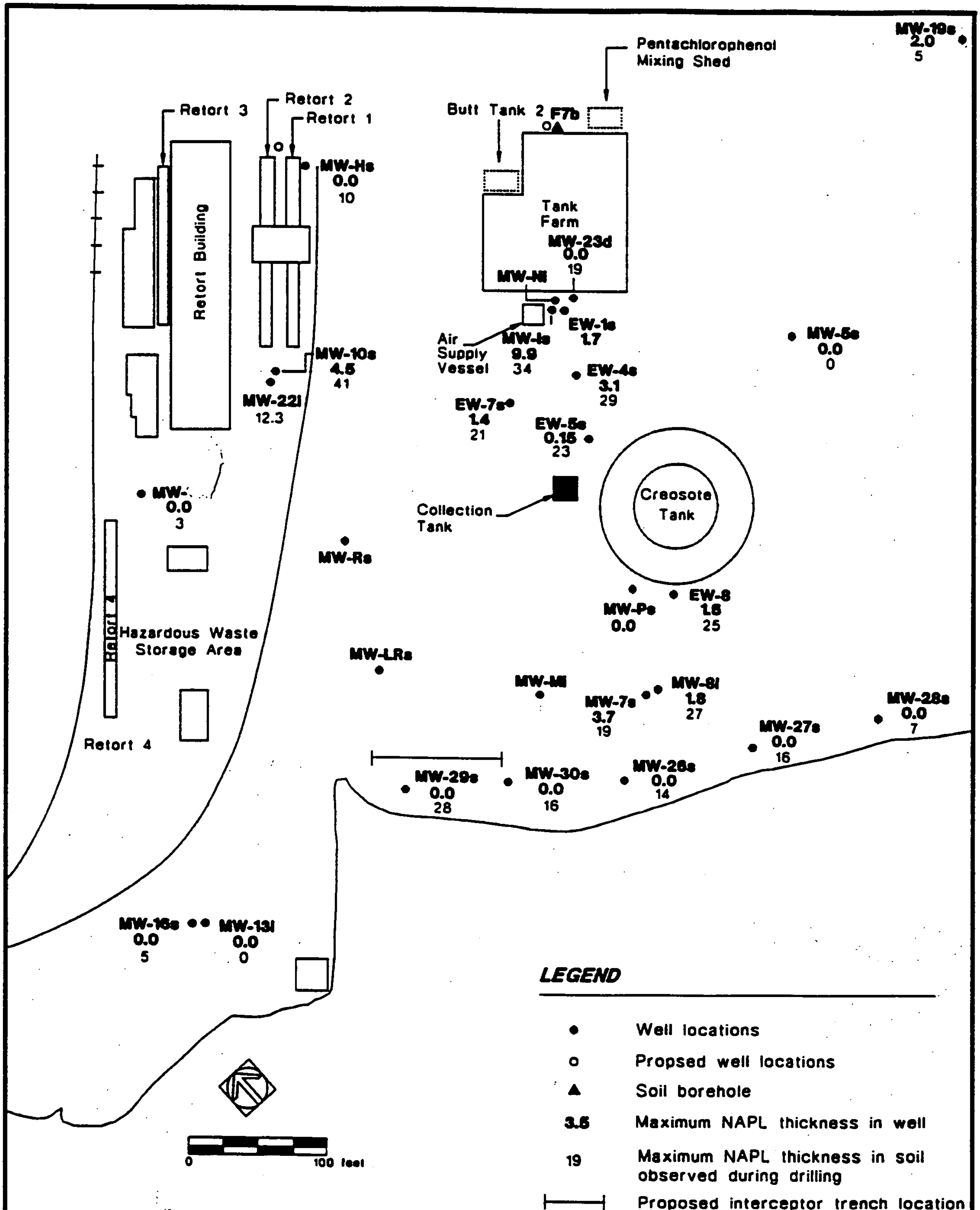

Figure 2. NAPL thicknesses and contaminated soil intervals for wells in the former tank farm area.

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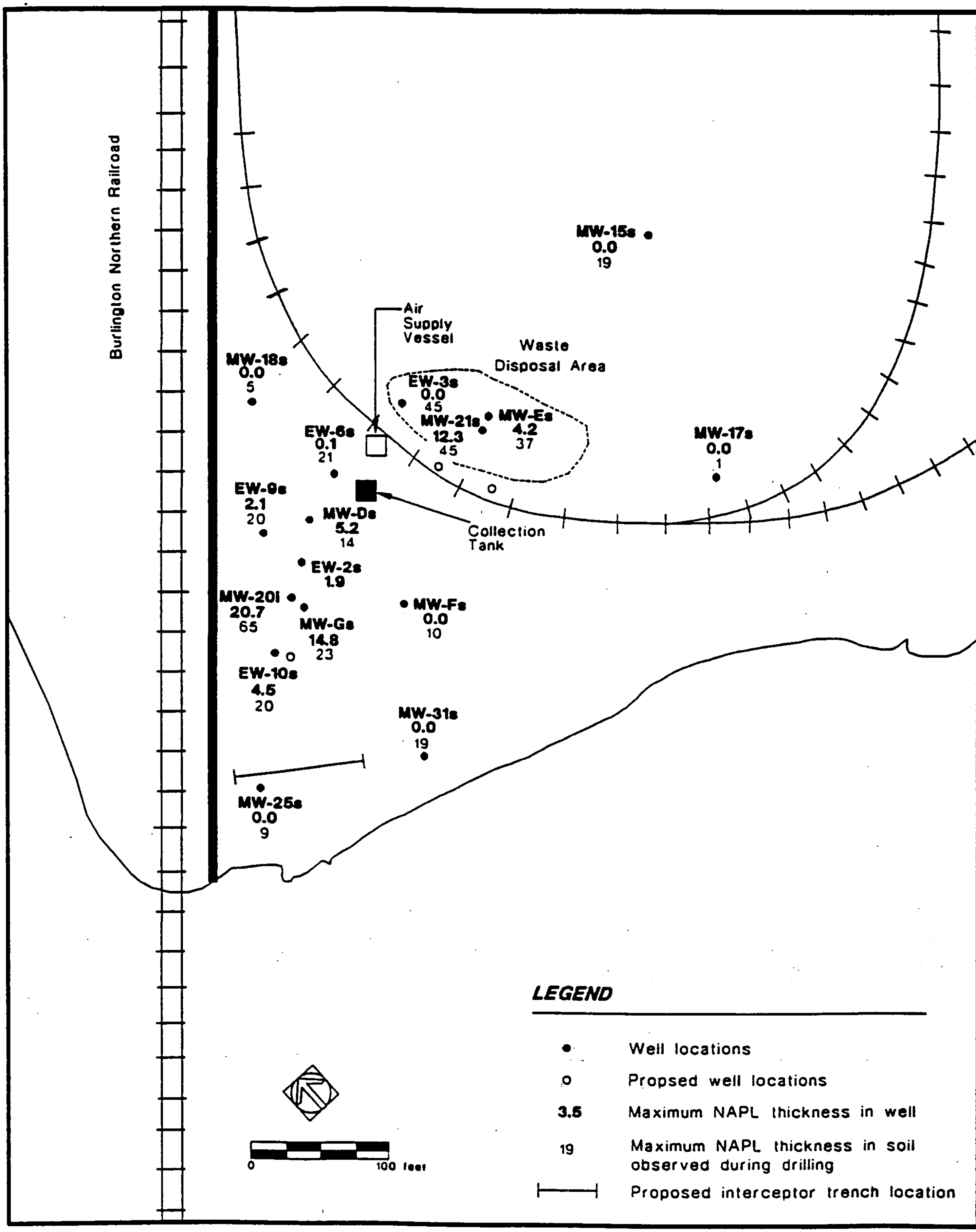


Figure 3. NAPL thicknesses and contaminated soil intervals for wells in the former waste disposal area.

Techniques for measuring NAPL thickness and extraction rates were developed and modified in the field. DNAPL thickness is measured in the wells using water level sounders that operate with conductance. When the probe is lowered from the water into the DNAPL, the meter signal stops, providing an accuracy of 0.01 ft for the measurements. LNAPL is measured with an interface probe, which is able to distinguish the floating layer and water table surface within 0.01 ft in accuracy.

Rates of NAPL extraction are estimated from control settings on the pumping system. Once settings are adjusted to match the available yield from a well, the actual rate is determined by collecting and measuring NAPL in a graduated container. This rate is verified on a weekly basis and extrapolated to estimate total NAPL recovered.

NAPL accumulated in many of the NAPL-producing wells soon after installation and development; however, Well EW-9s, located immediately downgradient of the FWDA pond, did not contain any DNAPL until several months after development, when it was measured at over 2 ft. In wells MW-1s, MW-7s, MW-10s, MW-19s, MW-21s, EW-1, and EW-2, NAPL accumulation did not occur until 1 to 3 years after installation. The LNAPL in well MW-10s was not measurable in the well until 2 years after installation, when it was measured at over 8 ft in thickness. Maximum NAPL thicknesses were not recorded in any of the wells until months or years after installation. These observations suggest the pools are currently active. It is likely that pulsed migration is occurring along DNAPL migration pathways. This migration is controlled by such factors as the volume and timing of the original release, hydraulic conditions in the aquifer and river, and the shape of the aquitard surfaces.

Many of the well boreholes that had significant thicknesses of visible NAPL in the soil have not had NAPL accumulate in the well (see Tables 1 and 2). Examples of this include wells EW-3, EW-6, and the beach wells, which have never contained sufficient NAPL to allow extraction. However, these wells are considered potential NAPL extraction wells because they are located within a migration pathway and a NAPL pool has migrated through at some time in the site history.

The NAPL pools feeding into the high-yielding wells appear to be very persistent. Wells MW-Is (TFA) and MW-20i (FWDA) have been purged of all NAPL repeatedly over several years and always recover to original thickness. Well EW-1 was tested by McCormick & Baxter in 1989 with dual pumping and was determined to be very productive with DNAPL yields. A similar test conducted 4 years later during this performance evaluation provided the same results. Because NAPL levels and well yields appear to be consistent over a period of several years, it is likely that the NAPL pools represent a relatively large source. In some areas, such as at the TFA, substantial NAPL pools may be accumulated in depressions on the silt aquitard. However, persistent NAPL pools have also been identified in areas where the silt aquitard is not present, such as downgradient of the FWDA.

Characteristics of the NAPL found in each of the wells are summarized in Table 3. The NAPL observed during drilling is indicated as an interval in the soil column and can be

TABLE 3. NAPL CHARACTERISTICS SUMMARY

Well Number	Installation Date	Total Depth Drilled (ft)	NAPL Soil Interval[a] (ft)		NAPL Soil Thickness[b] (ft)	Maximum Thickness (ft in well)		Temp[c] (°F)	Density[d] (g/cm³)	Kinematic Viscosity (cSt)
			From	To		DNAPL	LNAPL			
Tank Farm Area										
MW–Is	07/01/84	40.0	0.0	34.0	34.0	9.93		50.0	1.033	70.0
MW–Ps	8/84	89.0	0.0	0.0	0.0	0.0	0.0			
MW–7s	11/15/90	42.0	23.0	42.0	19.0	3.67	2.76	53.6	1.048	17.6
MW–8i	01/21/91	65.5	38.0	65.5	27.5	1.78		49.5	1.073	<17.5
EW–1s	10/01/87	NA	NA	NA	0.0	1.75		50.0	1.023	50.6
EW–4s	08/12/92	37.5	5.0	34.5	29.5	3.12	1.50	48.2	1.012	38.5
EW–5s	08/14/92	39.5	16.0	39.5	23.5		0.15			INS
EW–7s	08/28/92	39.5	15.5	36.5	21.0	0.56	1.40			
EW–8s	09/01/92	64.5	30.0	55.5	25.5	1.65				
Former Waste Disposal Area										
MW–Ds	09/28/83	32.0	18.0	32.0	14.0	5.25		49	1.025	23.1
MW–Es	07/10/84	48.0	2.0	39.0	37.0	4.20	2.97			
MW–Gs	07/01/84	39.5	16.5	39.5	23.0	14.85	2.34	51.0	1.010	<17.5
MW–18s	11/20/90	57.0	38.0	43.0	5.0					
MW–20i	01/03/91	88.0	21.0	86.0	65.0	20.67		53.6	1.012	<17.5
MW–21s	01/19/91	57.5	1.5	47.0	45.5		12.30	50.0	0.998	<17.5
EW–2s	10/01/87	NA	NA	NA	0.0	1.86		50.0	1.024	INS
EW–3s	07/30/92	50.0	5.0	50.0	45.0					
EW–6s	08/17/92	50.5	20.0	41.5	21.5	0.10		50.0	1.008	<17.5
EW–9s	09/04/92	69.5	33.0	53.0	20.0	2.08		53.6	1.029	30.8
EW–10s	09/23/92	61.5	15.0	35.0	20.0		4.50	53.6	0.998	<17.5
Other Areas										
MW–10s	02/12/91	41.7	1.0	41.7	40.7		8.08			
MW–19s	11/12/90	32.0	28.0	32.0	4.0	2.01		51.0	1.038	INS
MW–22i	07/10/91	63.3	32.0	56.0	24.0	0.66		53.6	1.024	<17.5

Note: Kinematic viscosity = the ratio of absolute viscosity to density; measured in centistoke (1 X 10 $^{-6}$ m^2/sec)
NA – information not available
INS – insufficient or inadequate sample

[a] Depth interval below ground surface with visible NAPL sheen or product in soils
[b] Thickness represents total soil interval with visible NAPL
[c] Temperature of NAPL when density and viscosity measurements conducted in field
[d] Values greater than 1.000 represent DNAPL; values below 1.000 represent LNAPL

compared to the total depth drilled and maximum NAPL thickness measured in the well. For example, in well MW-20i, an estimated 65 ft of the borehole (total depth of 88 ft) contained visible NAPL. The maximum measured thickness of NAPL in the well is less than 21 ft, which indicates a substantial amount of residual NAPL in the soils. In most of the wells, this visible residual in the soil is of much greater thickness than the measured NAPL.

Kinematic viscosity and density measurements are provided for wells that contained sufficient NAPL to sample. These measurements were taken from samples collected during current extraction efforts and are intended to provide a relative comparison between wells. Measurements indicate that the density of the NAPL is very similar to that of water (0.998 to 1.04 g/cm^3). Viscosity measurements indicate fluids are more viscous than water, but only by a small percentage, which would indicate that the NAPL is fairly mobile.

Viscosity data indicate a pattern at the TFA source area. Near the tank farm (well MW-Is), the kinematic viscosity is 70 centistokes (cSt) and decreases to 38.5 and 17.6 cSt at wells EW-4s and MW-7s, which are located toward the river. This is likely due to the more mobile (i.e., lower viscosity) constituents migrating further downgradient to the beach. This pattern was not repeated at the FWDA, where the highest viscosity measured was 30.8 cSt at EW-9s in the center of the NAPL area.

Currently, 20 extraction wells yield either LNAPL or DNAPL on a continuous or intermittent basis. These wells are shown in Figures 2 and 3 for the TFA and FWDA. Data from the pure NAPL extraction efforts are summarized in Table 4. Extraction data are summarized for three periods at the site: 1) the 2-year period that McCormick & Baxter extracted from wells, 2) PTI pilot testing efforts, and 3) full-scale operations. To date, an estimated 1,335 gal of NAPL have been extracted from 20 wells as pure product. The majority of these wells are located in the shallow aquifer zone; however, over 300 gal of DNAPL have been removed from a depth of 70 ft below ground surface in well MW-20i of the intermediate aquifer zone.

Only three wells (MW-Is, MW-20i, and MW-21s) are currently able to yield sufficient NAPL to sustain full-time unenhanced pumping. Yields of pure NAPL range from 11.4 to 32 gal per month. NAPL is allowed to accumulate in the other wells until there is sufficient thickness to extract, which results in a few gallons per month from most wells.

2.2 FIELD PROGRAM

The performance evaluation testing was conducted as outlined in Amendment No. 2 (PTI 1993) with target wells from the FWDA and TFA selected for evaluation. Testing methods included dual pumping, total fluids extraction, and a baildown test with recovery monitoring.

TABLE 4. PURE PHASE NAPL EXTRACTION SUMMARY

Well Number	Installation Date	McCormick Data 7/89 – 9/91 (gal extracted)	PTI Pilot Testing 10/91 – 2/93 (gal extracted)	Full Scale Operation 2/1/93 – 3/24/93 (gal extracted)	Sustainable NAPL[a] Extraction Rate of Pure Phase (extimated gal/mo.)	Total Extracted 7/89 – 3/24/93 (gal)	Comments
Tank Farm Area							
MW–Is	07/01/84	126.0	109.9	17.1	11.4	252.9	Rate variable
MW–Ps	8/84			0.0	I	0.0	Well located within plume area
MW–7s	11/15/90		3.0	1.0	I	4.0	1 gal per purge
MW–8i	01/21/91		0.3	0.0	I	0.3	Less than 1 gal per purge
EW–1s	10/01/87	205.0		0.0	I	205.0	Few gal per purge
EW–2s	10/01/87	56.0	0.6	0.0	I	56.6	1 gal per purge
EW–3s	07/30/92		1.0	0.0	I	1.0	1 gal per purge
EW–4s	08/12/92		20.0	0.0	I	20.0	No pure product without enhancements
EW–5s	08/14/92		10.0	0.0	OW,I	10.0	No pure product without enhancements
EW–6s	08/17/92		1.0	0.0	I	1.0	1 gal per purge
EW–7s	08/28/92		1.3	0.0	I	1.3	1 gal per purge
EW–8s	09/01/92		1.3	0.0	I	1.3	1 gal per purge
Former Waste Disposal Area							
MW–Ds	09/28/83	110.0	2.4	8.0	I	120.4	1 gal per purge
MW–Es	07/10/84			0.0	NE	0.0	Well seasonally dry
MW–Gs	07/01/84	157.0	0.6	0.5	I	158.1	MW–20 draws NAPL from MW–G
MW–18s	11/20/90			0.0	I	0.0	NAPL observed during drilling; plume area
MW–20i	01/03/91		283.7	33.0	32.0	316.7	Sustainable rate calculated @ 1 gpd
MW–21s	01/19/91		3.1	30	24	33.1	Sustainable rate calculated @ 0.8 gpd; LNAPL only
EW–9s	09/04/92		2.4	0.0	I	2.4	1 gal per purge
EW–10s	09/23/92			0.3	NE	0.3	LNAPL only
Other Areas							
MW–10s	02/12/91			5.0	I	5.0	Recent LNAPL
MW–19s	11/12/90		1.0	0.0	I	1.0	1 gal per purge
MW–22i	02/23/93		1.0	0.0	I	1.0	1 gal per purge
Performance Evaluation						143.3	Total extracted during 4/93 testing
Total Extracted		**654**	**442**	**95**	**67**	**1,335**	

Note: gpd – gal per day
I – intermittent purge
LNAPL – light nonaqueous–phase liquid
NAPL – nonaqueous–phase liquid
NE – not established
OW – oil/water mixture

[a] Sustainable rate determined by field testing; NAPL extraction rates were optimized to highest rate that did not produce groundwater

Each of the tests involved the extraction of groundwater from the tested well. The maximum rate of groundwater that could be extracted from each well was controlled by the well diameter. In 2-in.-diameter wells, a single 1.5-in.-diameter pneumatic pump was used to extract a maximum of 0.5 gal per minute (gpm) of water. In the 4-in.-diameter and larger wells, additional pneumatic pumps or a submersible pump were used to extract groundwater at higher rates (0.6 to 6 gpm). Higher extraction rates generally produce better results in the dual pumping and total fluids tests due to greater drawdowns and increased hydraulic gradients into the wells.

Dual pumping tests were conducted on seven wells; three in the FWDA and four in the TFA. Dual pumping tests involved removing DNAPL and groundwater with separate pumps. One pump was set at the bottom of the well to extract DNAPL and the other pump (or pumps) near the top of the water column to remove groundwater. Drawdown induced by groundwater pumping was intended to cause upwelling of the DNAPL into the well screen and potentially result in increased DNAPL yields.

The dual pumping test in well EW-1s at the TFA was very successful, so the test was extended to 96 hours with groundwater extracted at 2 gpm. DNAPL was collected in a drum to allow quantification of sustainable extraction rates.

Total fluids tests were conducted on two extraction wells in the TFA. These tests were performed with a submersible pump at 2 to 6 gpm and samples were collected at routine intervals to allow estimations of percentage of DNAPL in the total fluids.

LNAPL and groundwater levels were monitored in EW-10s to determine the relationship with the river stage. A baildown test was also conducted on EW-10s. The baildown test involved purging LNAPL from the well and monitoring recovery over time.

Groundwater and NAPL samples were collected from all wells during dual pumping and total fluids tests. These samples were centrifuged to estimate the ratio of NAPL to groundwater; the groundwater portion of the samples was tested for oil and grease (Method 5520B) to provide data for planning future disposal options. NAPL samples are archived at the McCormick & Baxter site for further testing, if necessary.

2.3 ENHANCED EXTRACTION TESTING

Performance evaluation testing was conducted on 10 wells at the FWDA and TFA. Test results are summarized in Table 5 and individual test details are provided in Appendix A. Results are discussed by test area below.

Several methods were used in the field to estimate the volume of fluids extracted and the rates of extraction. Pure-phase NAPL extraction rates were measured in the field by collecting NAPL in containers and calculating rates based on pumping time and measured volumes. Groundwater extraction rates were measured with a flow meter and stop watch. For the total fluids recovery tests, the percentages of NAPL and water were

TABLE 5. PERFORMANCE EVALUATION TESTS

Test	Date	Well	Total Time (hrs)	Gallons Removed		Sustainable Rate (gpd)	Remarks
				NAPL	Water		
Dual Pumping	3/09/93	MW−20i FWDA	8.5	12.0	165	1.0	Groundwater pumped at 0.5 gpm (720 gpd) Maximum upwelling of DNAPL = 12.6 ft DNAPL evacuated from well Earlier extraction data suggest 1 gpd sustainable DNAPL rate
Dual Pumping	3/15/93	EW−1 TFA	7.5	15.0	850	42.0	Groundwater pumped at 2 gpm (2,880 gpd) Maximum upwelling of DNAPL = 0.5 ft; upwelling occurs when DNAPL pumped at rate less than 19 gpd DNAPL thickness sustained at 0.69 ft when DNAPL pumped at 42 to 49 gpd
Total Fluids	3/16/93	EW−1 TFA	4.0	4.5	501	27.0	Total fluids pumped at 2 gpm (2,880 gpd) Maximum upwelling of DNAPL = 0.5 ft Sustainable rate would produce 2,880 gpd total fluids with DNAPL as 1−3% (27 gpd)
Dual Pumping	3/17/93	MW−22 TFA	6.0	0.5	360	0.0	Groundwater pumped at 1.1 gpm (1,584 gpd) Maximum upwelling of DNAPL = 0.12 ft[a] DNAPL evacuated from well
Dual Pumping	3/18/93	EW−9 FWDA	7.0	1.5	250	0.0	Groundwater pumped at 0.6 gpm (864 gpd) Slight upwelling of DNAPL[a] DNAPL evacuated from well
Bail Down (LNAPL)	3/19/93	EW−10 FWDA	3.5	2.0	0	NA	LNAPL recovered to maximum thickness in 1 hr Maximum thickness coincides with low tide
Dual Pumping	3/22/93	EW−4 TFA	7.5	1.7	330	7.6	Groundwater pumped at 0.8 gpm (1,152 gpd) Maximum upwelling of DNAPL = 1.52 ft DNAPL extraction at 2.9 gpd at maximum upwelling During first 4 hours, pumped 60% water and 40% DNAPL; after 4 hours, 100% DNAPL
Total Fluids	3/23/93	EW−4 TFA	6.5	100.0	1,000	288.0	Total fluids pumped at 2, 4, and 6 gpm (2,880; 5,760; and 8,640 gpd) Upwelling did not occur Sustainable rate would produce 2,880 gpd total fluids with DNAPL as 5−10% (288 gal) Water levels decreased by 5.9 ft over 6.5 hr test

TABLE 5. (cont.)

Test	Date	Well	Total Time (hrs)	Gallons Removed NAPL	Gallons Removed Water	Sustainable Rate (gpd)	Remarks
Dual Pumping	3/24/93	MW-D FWDA	6.1	1.5	165	0.0	Groundwater pumped at 0.4 gpm (576 gpd) Maximum upwelling of DNAPL = 0.89 ft[a] DNAPL evacuated from well
Dual Pumping	3/25/93	MW-7s TFA	6.3	0.6	165	0.0	Groundwater pumped at 0.5 gpm (720 gpd) Slight upwelling of DNAPL[a] DNAPL evacuated from well
Dual Pumping	3/30-4/1/93	EW-1 TFA	96	54	11,280	13.5	Groundwater pumped at 2 gpm (2,880 gpd) Maximum upwelling of DNAPL = 2.53 ft DNALP thickness not sustainable at 42 to 49 gpd 50% of test on intermittent basis

Note: FWDA – former waste disposal area
gpd – gallons per day
gpm – gallons per minute
NA – data not available or not applicable
TFA – tank farm area

[a] Upwelling occurred prior to DNAPL extraction during groundwater extraction

estimated by centrifuging the sample and measuring the relative volumes of NAPL and water in a graduated cylinder.

2.3.1 *Former Waste Disposal Area*

Three wells were tested with dual pumping (MW-20i, MW-Ds, and EW-9s); EW-10s was also investigated to evaluate river stage effects on extraction of LNAPL.

Long-term DNAPL yields could not be increased at the FWDA by dual pumping. In well MW-20i, substantial upwelling was initially observed and yields increased. However, as the test continued, the DNAPL was slowly depleted and groundwater pumping could not stimulate increased yields. Pure-phase pumping of DNAPL in MW-20i at 1 gal per day (gpd) appears to be as efficient as dual pumping and does not produce the large quantities of groundwater. MW-Ds and EW-9i started with small accumulations of DNAPL, but extraction steadily depleted these layers throughout the tests. These results suggest that the maximum yields attainable from MW-Ds and EW-9i are from intermittent purging of pure product conducted once or twice a month. Higher groundwater extraction rates may be able to induce increased DNAPL yields, but this cannot be tested due to the small diameter of the wells.

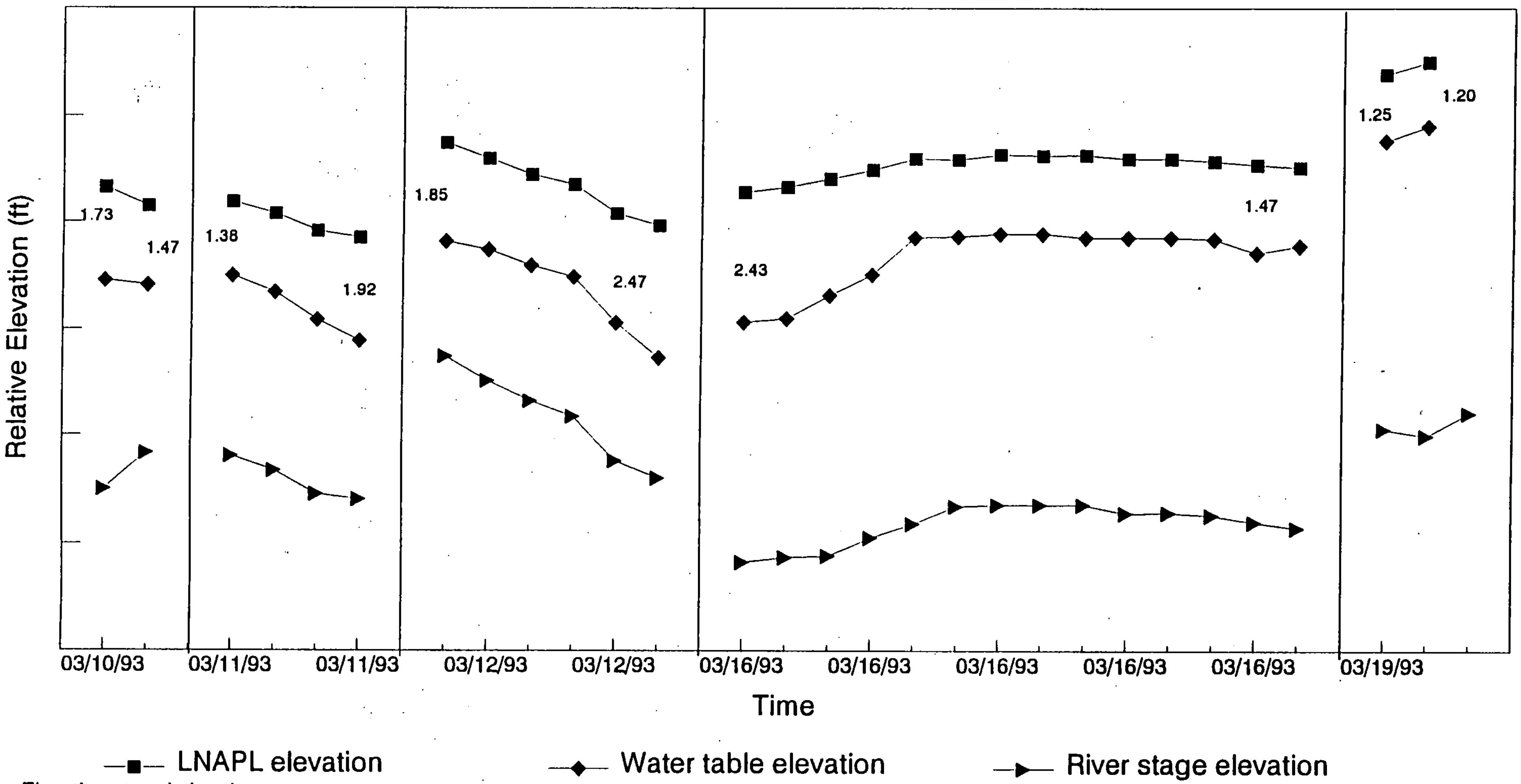
Well EW-10s is located between the major FWDA DNAPL pool (MW-20i) and the beach. This well initially did not contain any NAPLs; however, after a period of 3 months, over 4 ft of LNAPL appeared in the well. This LNAPL is floating on the shallow water table and if not captured will eventually migrate out into the sediments. In order to evaluate options to either extract or intercept this LNAPL pool, the relationship between the well and river stage was investigated.

The thickness of LNAPL in EW-10s is compared to the river stage over a period of several days in Figure 4. The relative depths to LNAPL and the water table are shown at the top of the figure. The difference between these lines represents the LNAPL thickness at any point in time. Relative river stage elevation is shown as a line at the bottom of the figure. The slope of these lines represents rising and falling water levels caused by tidal fluctuations.

The shallow aquifer at EW-10s is in direct hydraulic communication with the river as the aquifer water table and LNAPL layer respond to the rise and fall of the river. The measured thickness of LNAPL is related to whether the water table is rising or falling. Rising water causes the apparent LNAPL thickness to decrease and falling water causes the apparent LNAPL thickness to increase. During the monitoring periods shown on Figure 4, a 1-ft rise or fall in river level corresponds to a 0.4- to 0.9-ft change in NAPL level.

A baildown test was attempted at EW-10s to provide qualitative data on potential yields from the well. River levels were measured before, during, and after the test. After purging 1.25 ft of LNAPL from the well, recovery was very slow for 30 minutes, then

Figure 4. EW–10 LNAPL Thickness
McCormick & Baxter Site



Elevations to relative datum

increased quickly to a thickness of 2.30 ft. With time, the LNAPL thickness decreased as the river level began to rise. The erratic recovery was affected by the river stage (ongoing tidal fluctuation) and is therefore difficult to interpret. However, the rapid recovery of LNAPL suggests that the LNAPL pool is mobile and that this would be a good recovery well.

2.3.2 Tank Farm Area

Four wells were tested in this area using dual pumping and total fluids testing methods. EW-1s and EW-4s were tested using both methods; MW-7s and MW-22i were tested by dual pumping only. Results of these tests are summarized in Table 5.

In most cases at the TFA, enhanced techniques increased DNAPL yields to wells. Although upwelling was minimal, DNAPL flows were induced and appear to be consistent at levels ranging from 8 to over 100 gpd. Total fluids recovery produced higher DNAPL yields than dual pumping, but offered a major disadvantage by producing a mixture of oil and water that is difficult to separate. Dual pumping produced clear groundwater (i.e., with no visible oil) and pure-phase DNAPL.

Although extensive accumulations of DNAPL do not occur in EW-1s, dual pumping with 2 gpm water appears to cause enough upwelling to sustain DNAPL extraction of 13.5 gpd over a 4-day period. These results contrast with the minor DNAPL recovery rates obtained from direct pumping (i.e., NAPL only) where the well is quickly purged and requires many days to recover.

An estimated 27 gpd of DNAPL was recovered during a total fluids test at EW-1, but the DNAPL was recovered as 1 percent of the total groundwater. The product phase was suspended in the water and settled out very slowly in the sample bottles.

The dual pumping test at EW-4 induced upwelling of approximately 1 ft, resulting in a DNAPL yield of 8 gpd. However, the total fluids test produced an oil/water mixture of approximately 5 percent product, representing 140 gpd DNAPL. Again, the mixture appeared to separate slowly in the sample bottle.

A dual pumping test on MW-7s near the beach did not produce increased yields of DNAPL. However, this well is 2 in. in diameter and groundwater extraction was limited to 0.5 gpm. Higher groundwater extraction rates may be able to induce higher NAPL yields in this area.

2.4 ANALYTICAL RESULTS

Groundwater samples from representative tests were analyzed for oil and grease to provide an indication of water quality in the aquifer with time and allow estimation of remediation costs. Data are summarized in Table 6. In the dual pumping tests,

TABLE 6. PERFORMANCE TESTING LABORATORY RESULTS

Test	Well No.	Oil and Grease (mg/L)	Comments
Dual pumping	MW-Ds	22	Water sample from upper pump 1.75 hours into test
Dual pumping	EW-1s	564	Water sample from upper pump 7 hours into test
Dual pumping	EW-4s	6,177	Water sample from upper pump 5 hours into test; sample contained approximately 5% NAPL
Total fluids	EW-1s	23 473	Water sample (supernate) at 1.2 and 3.5 hours into test
Total fluids	EW-4s	941 1,010 1,870	Water sample (supernate) at 1, 5 and 6.5 hours into test

concentrations of organic compounds in the groundwater phase ranged from 22 mg/L in MW-Ds to 6,177 mg/L in EW-4s. The sample from EW-4s contained visible droplets of NAPL. In the total fluids test, organic compound concentrations ranged from 23 to 1,870 mg/L; concentrations increased with pumping time. It is assumed that as the capture zone of the pumping well expands with time, highly contaminated water is drawn into the well.

3.0 SUMMARY AND RECOMMENDATIONS

Results of the performance evaluation testing are summarized below with recommendations for expanding the system and applying enhanced recovery methods to specific wells. A summary of recommendations with specific rationale is also included in Table 7. Well locations are shown in Figures 2 and 3.

3.1 FORMER WASTE DISPOSAL AREA

Testing in the FWDA indicates that enhancement techniques are not effective in increasing yields of DNAPL to wells. Dual pumping was able to cause DNAPL upwelling at the beginning of the tests and resulted in short-term increased yields; however, after a few hours of testing, the DNAPL layer was depleted and the wells yielded only groundwater. Continuous pumping of the groundwater did not induce DNAPL into the wells, suggesting that once the DNAPL in wellbore and sandpack storage was removed, the dual pumping was no more efficient than direct extraction. Possible explanations for the results include lack of an aquitard that could isolate a substantial pool layer and low groundwater pumping rates, which were limited to less than 1 gpm due to well diameter constraints.

At this time, enhanced extraction techniques are not proposed for the existing FWDA DNAPL wells. Extraction operations should continue with pure-phase pumping on a continuous or intermittent basis depending on the yield from individual wells. Larger-diameter wells could be installed to replace the 2-in-diameter wells in this area, allowing greater flexibility for enhanced recovery. At this time it is recommended that well replacement be deferred until the long-tern use of enhanced techniques at the TFA can be evaluated.

Additional wells for extraction of LNAPL or DNAPL and a pilot interceptor trench for removal of LNAPL are proposed for the FWDA. The trench should be screened to intercept the seasonal water table during low river stage (i.e., summer months). LNAPL wells should be screened across the seasonal range in the shallow water table. DNAPL wells should be screened across the most visibly contaminated soil intervals. The DNAPL well boreholes will not be drilled past the NAPL-contaminated soils and into visibly uncontaminated soils below. Additional wells that are constructed at the site should be a minimum of 4-in. diameter to allow flexibility in applying enhanced recovery techniques.

Specific recommendations for the FWDA are presented below in the order that they appear in Table 7.

TABLE 7. RECOMMENDATIONS

Area	Proposed Task	Location	Rationale
Former Waste Disposal Area	Install 2 shallow extraction wells	Downgradient of MW-21s	MW-21s has yielded substantial LNAPL and has contained a measured thickness of over 8 ft; net shallow groundwater flow direction is toward the Willamette River.
	Conduct ground-water depression and LNAPL skimming test	MW-21s	LNAPL has low viscosity and yields could be substantially increased; water table depression will also allow greater area of influence for extraction well.
	Install intermediate extraction well	Nested with EW-10s, which is downgradient of MW-20i	Intermediate zone DNAPL pool is located immediately upgradient at MW-20i, which has yielded substantial quantities during pure-phase pumping; EW-10s is along the migration pathway to the beach and sediments where there currently is no monitoring or extraction point for intermediate DNAPL pools.
	Install 100-ft pilot LNAPL interceptor trench	Along beach downgradient of EW-10s where over 4 ft of LNAPL has been measured	LNAPL is migrating on shallow water table at MW-10s toward beach to possibly discharge as seeps and contaminate sediments.
Tank Farm Area	Install shallow extraction wells	Two wells near DNAPL pools intersected by extraction wells EW-1s and EW-4s; a third well at back of tank farm near soil boring F7b	Extraction wells on downgradient side of tank farm have yielded substantial DNAPL in dual-pumping efforts; DNAPL pool is found on irregular aquitard surface at TFA; soil boring F7b at upgradient side of tank farm identified substantial visual NAPL, which suggests the NAPL pool extends throughout the tank farm area.
	Pilot scale dual pumping	Tank farm wells	Dual pumping was very successful during performance testing over 6-hour and 100-hour tests; the long-term success of dual pumping cannot be evaluated without long-term testing.
	Install 100-ft pilot LNAPL interceptor trench	Along beach downgradient near monitoring wells MW-29s and MW-30s where active LNAPL seeps have characterized for tens of years	LNAPL is migrating on shallow water table from tank farm and creosote tank areas; wells on beach have contained NAPL blebs, but are not of sufficient thickness to extract; trench will cover much wider area and possibly intercept fingers of NAPL.

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TABLE 7. (cont.)

Area	Proposed Task	Location	Rationale
Butt Tank and Waste Disposal Trench	Install shallow extraction wells	One well at the butt tank and two wells along the trench	Soil boring E9a at butt tank identified substantial visual NAPL, which suggests a NAPL pool originates from former tank; well MW-19s and soil boring F10a along trench indicate substantial NAPL, which suggests a NAPL pool originates along trench; trench borings also encountered a silt aquitard, which could confine DNAPL and allow higher success in extraction.
Retort Area	Install shallow extraction well for both LNAPL and DNAPL	Northeast end of retorts 1 and 2	MW-10s has contained over 4 ft of LNAPL and both MW-10s and MW-22i have contained NAPL, suggesting spills have occurred around the retorts.

3.1.1 Install Additional Extraction Wells

Based on the success of LNAPL extraction in well MW-21s, it is recommended that two additional shallow extraction wells be located downgradient of the former FWDA pond. These could be located along the railroad tracks on the river side of MW-21s, which would be an optimum location to intercept LNAPL layers that are migrating towards the beach.

3.1.2 Perform Water Table Depression and LNAPL Skimming

Water table depression and LNAPL skimming are recommended for pilot testing at MW-21. This well has yielded product consistently and the LNAPL layer recovers quickly to several ft in thickness once the extraction is stopped. The water table depression may increase yields by increasing the gradient toward the well, which will enlarge the effective radius of influence of the well. Other LNAPL enhancement techniques such as vacuum-enhanced recovery should be considered in the future once primary techniques are exhausted.

3.1.3 Install Intermediate Extraction Well

The DNAPL pool at MW-20i has consistently yielded creosote and recovers to over 20 ft in thickness once the extraction is stopped. There are currently no monitoring points for this DNAPL downgradient of MW-20i toward the beach. An intermediate well, to be clustered with EW-10s, is recommended to investigate the potential for migration of DNAPL toward the river. If DNAPL is encountered, it should be extracted by direct techniques and intermediate wells along the beach should be considered.

3.1.4 Install Interceptor Trench at Beach

The LNAPL layer in well EW-10s is highly affected by river stage and tidal influences. The water table elevation and LNAPL thickness change daily with each tide, making extraction very difficult. When the river stage came up to a very high level, the LNAPL appeared to flow landward in response to the change in gradient direction. These observations suggest the LNAPL is very mobile and would therefore be expected to eventually migrate to the beach. An interceptor trench is recommended on the beach downgradient of EW-10s. Test pits should be excavated to search for LNAPL contaminants and optimize the placement of a 100-ft-long pilot trench that can be operated for the upcoming summer months. NAPL will be collected from wells or sumps at each end of the trench, with pneumatic pumps used to lift the product to the collection tank at the FWDA.

3.2 TANK FARM AREA

Testing in the TFA indicates that enhancement techniques are very effective at increasing NAPL yields in EW-1s and EW-4s, which are located near the source at the tank farm. Dual pumping caused minimal DNAPL upwelling, but resulted in sustainable yields ranging from 8 to 13.5 gpd. Total fluids recovery was also effective and produced even higher DNAPL yields; however, a negative impact of oil/water separation would be included in any total fluids effort. The relative success of these enhanced techniques at the TFA compared to the FWDA could be attributed to the aquitard, which acts as a collection barrier for the NAPL. A second consideration is the groundwater extraction rates, which were higher at the TFA due to larger well diameters.

Specific recommendations for the TFA are presented below in the order that they appear in Table 7.

3.2.1 Install Additional Shallow Extraction Wells

Based on the location of wells that yield DNAPL, three additional shallow extraction wells are recommended. Two wells can be placed downgradient, on the river side, of EW-7 and EW-5 to define the extent of the pool. Although these wells have not been good producers during direct extraction, they have both contained substantial NAPL-contaminated soil (Table 1), suggesting that they are located within the major NAPL migration pathway. One well is recommended at the upgradient side of the tank farm near soil borehole F7b, which encountered substantial NAPL in soils. Once the tank farm is demolished, extraction wells should be placed within the existing footprint.

3.2.2 Perform Pilot Scale Dual Pumping

Pilot scale dual pumping from existing and new extraction wells is recommended for a period of several months. Dual pumping produced between 8 and 13.5 gpd of DNAPL and would likely not require oil/water separation. DNAPL can be pumped directly into the existing storage tank. Groundwater could be pumped at approximately 2 gpm and temporarily stored in storm water collection tank #4, which has a total capacity of 750,000 gal. This water could subsequently be treated with the storm water.

Due to the uncertainty associated with long-term DNAPL yields, is recommended that enhanced extraction efforts be conducted following a phased approach. The existing water storage tank offers several months of storage capacity for groundwater, and if the DNAPL is depleted after several weeks, substantial savings will be recognized because a storage facility and water treatment plant were not constructed.

Total fluids extraction should be evaluated with an engineering assessment to determine the costs associated with this technique. Although DNAPL yields are higher with total fluids recovery, oil/water separation may be necessary prior to treatment. Oil and grease data (Table 6) and the remedial investigation report (PTI 1992c) provide a summary of the nature and magnitude of contaminants expected in the discharge from the wells. Archived samples for the performance testing are stored at the site.

3.2.3 Install Interceptor Trench at Beach

A pilot interceptor trench (as described for the FWDA) should be installed on the beach downgradient of the TFA. This area has contained active seeps for years and is downgradient of the tank farm and creosote tank. Test pits should be spaced along the beach from the bulkhead to MW-28s to optimize the trench location. An access road will be required for moving equipment and soil cuttings back onto the property.

3.3 OTHER TARGET AREAS

Two other areas of the site are considered to have a good potential for DNAPL extraction, but are presently not being tested. The retort area and butt tank/waste disposal trench should be investigated with the installation of extraction wells and enhanced extraction techniques.

Soil boreholes at the butt tank and former waste disposal trench (Figure 1) indicated highly contaminated soils to the underlying aquitard. One extraction well is recommended adjacent to the butt tank and two wells along the trench south of MW-19s. One of the extraction wells should be targeted for the site of soil borehole F10a.

Well MW-10s, at the downgradient end of the retort, has contained over 8 ft of LNAPL and Well MW-22i, located next to it, has contained DNAPL. Retorts number one and two represent a large potential source that should be investigated. One shallow extraction well is recommended at the upgradient retort door. Well MW-H, located near this location, has not shown NAPL in the past, but is improperly constructed and is not representative of NAPL conditions.

4.0 REFERENCES

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PTI. 1993. Amendment No. 2 to Task Order 35, technical support for McCormick & Baxter site. Letter dated February 24, 1993 to Paul Burnet, Oregon Department of Environmental Quality. PTI Environmental Services, Bellevue, WA.

APPENDIX A

Results from Dual Pumping, Total Fluids Extraction, and Baildown Tests

CONTENTS

DUAL PUMPING TEST — EW-1

Date of test: 3/15/93

Start time: 10:32
Finish time: 18:09

10:32	Static conditions	Depth to water = 24.55 DNAPL thickness = 1.19
11:07	Begin pumping water	Calibrate
11:30	Pumping water; monitor thickness	Water pumped @ 2 gpm DNAPL thickness = 1.19
12:00	Monitor	Thickness = 1.29
12:05	Begin pumping DNAPL	Thickness = 1.38 DNAPL @ 31.4 mL/min (12 gpd)
12:30	Monitor	Thickness = 1.56
12:40	Monitor/check rate	Thickness = 1.62 52 mL/min (19.8 gpd)
12:45	Water level decreased 1.8 ft	Lower water pump
12:55	Monitor/check rate	Thickness = 1.7 363 mL/min (24.0 gpd)
13:05	Monitor/check rate	Thickness = 1.53 305 mL/min (116.0 gpd)
13:20	Monitor	Thickness = 1.27
13:25	Check DNAPL rate	375 mL/min (142.0 gpd)
13:30	Monitor/check rate	Thickness = 0.85 205 mL/min (78.0 gpd)
13:40	Monitor/check rate	Thickness = 0.81 135 mL/min (51.4 gpd)
14:00	Monitor/check rate	Thickness = 0.75 128 mL/min (48.7 gpd)
14:25	Monitor/check rate	Thickness = 0.69 108 mL/min (41.1 gpd)
15:25	Monitor/check rate	Thickness = 0.66 125 mL/min (47.6 gpd)
16:00	Monitor/check rate	Thickness = 0.63 111.6 mL/min (42.4 gpd)
16:20	Lower water pump to 30 ft; increase water rate	Water pumped @ 4 gpm
16:30	Monitor; decrease water rate lower water pump to 31 ft	Thickness = 0.73 Water pumped @ 2 gpm
16:40	Monitor	Thickness = 0.76

DUAL PUMPING TEST — EW-1. (cont.)

16:50	Check DNAPL rate	116.6 mL/min (44.4 gpd)
17:00	Monitor	Thickness = 0.72
17:30	Monitor/check rate	Thickness = 0.66 115 mL/min (43.8 gpd)
17:50	Monitor/check rate	Thickness = 0.64 115 mL/min (43.8 gpd)
18:09	End test	Thickness = 0.63 ft Total water = 850 gal Total DNAPL = 15 gal

Note: Thicknesses reported in ft
DNAPL - dense nonaqueous-phase liquid
gpd - gal per day
gph - gal per hour
gpm - gal per minute

Summary: Pumping only groundwater from EW-1s appears to cause some upwelling (0.2 ft/hour). Under dual pumping conditions, upwelling occurred more rapidly (0.38/hour). Based upon the results of this test, EW-1 could be added to the extraction system as a permanent producer under a dual pumping scheme. Pumping product at a rate of 100 mL/min (38 gpd) and water at 2 gpm (2,880 gpd) would produce 1,140 gal of product and 86,400 gal of water a month. However, this was a 6-hour test and long-term yields would be expected to be lower.

CONTINUAL DUAL PUMPING TEST — EW-1

Date of test: 3/29 - 4/2/93

Start time: 13:50
Finish time: 11:52

Date	Time	Event	Comments
3/29	13:50	Begin pumping water	Pump water @ 2 gpm
	14:45	Begin pumping product	DNAPL thickness = 1.23 Pumping at 105 mL/min (40 gpd)
	16:45	Monitor	DNAPL thickness = 0.28 Pumping at 105 mL/min (40 gpd)
3/30	08:30	Pumping water and product; end DNAPL pumping	DNAPL thickness = 0.23 Pumping @ 850 mL/min (323 gpd) prior to shut down
	10:00 to 15:00	Monitor thickness; continue pumping water	DNAPL thickness remained 0.0
3/31	09:00	Begin pumping product	DNAPL thickness = 2.53 Pumping at 90 mL/min (34 gpd)
	13:00	Purged DNAPL, end DNAPL pumping	DNAPL thickness 0.0
	15:30	Monitor thickness	DNAPL thickness = 0.51
4/1	09:30	Start DNAPL pump	DNAPL thickness = 2.30 Pumping at 85 mL/min (32 gpd)
	15:45	Monitor thickness	DNAPL thickness = 0.31 Continue pumping at 85 mL/min (32 gpd)
4/2	08:00	Purged DNAPL, end DNAPL pumping	DNAPL thickness = 0.0
	11:52	End dual pump test	DNAPL thickness = 0.61 Total DNAPL extracted = 54 gal Total water removed = 11,280 gal

Note: Thicknesses reported in ft
DNAPL - dense nonaqueous-phase liquid
gpd - gal per day
gpm - gal per minute

Summary: Water was pumped continually during the 4-day test. Upwelling patterns in the initial testing of EW-1s are reflected in this test. However, the well cannot sustain yields previously estimated. DNAPL could not be sustained at rates of 32–40 gpd. The dual pumping in EW-1 does enhance recovery at this well, since it doesn't accumulate substantial thicknesses for periodical purging.

DUAL PUMPING TEST — EW-4

Date of Test: 3/22/93

Start time: 09:26
Finish time: 17:00

Time	Event	Comments
09:26	Static conditions	Depth to groundwater = 24.20 DNAPL thickness = 1.52
10:10	Begin pumping water	0.8 gpm
10:38	Monitor NAPL thickness	Thickness = 1.59
10:42	Begin pumping NAPL	0.12 gph (2.9 gpd); 60% water
12:13	Monitor NAPL thickness	Thickness = 1.84; 0.12 gph (2.9 gpd) DNAPL sample contains 70% water Water sample contains 5% DNAPL
13:37	Monitor DNAPL thickness	Thickness = 2.46; 0.12 gph (2.9 gpd)
14:56	Monitor	DNAPL = 100%; water 5% DNAPL
15:09	Increase DNAPL pumping rate; monitor	0.84 gph (20.3 gpd); thickness = 3.04
16:12	Monitor DNAPL thickness	Thickness = 1.64; 0.84 gph (20.3 gpd)
16:30	Decrease DNAPL pumping rate; monitor	0.32 gph (7.6 gpd); thickness = 1.29
17:00	Final measurements; end test	Depth to groundwater = 25.60 Thickness = 1.28; 0.32 gph (7.6 gpd) Total DNAPL removed = 1.7 gal Total water removed = 330 gal

Note: Thicknesses reported in ft
DNAPL - dense nonaqueous-phase liquid
gpd - gal per day
gph - gal per hour
gpm - gal per minute

Summary: During the first 0.5 hour of pumping groundwater, only 0.07 ft of upwelling of product occurred. After 1.5 hours of dual pumping, 0.32 ft of upwelling of product occurred and consisted of approximately 70 percent product within the water as a distinct phase that subsequently settled. The groundwater pumped contained approximately 5 percent product as a separate phase. Pure DNAPL and maximum thickness of 3.04 ft was produced after 4 hours of pumping DNAPL at 0.12 gph (3.0 gpd); this is an upwelling of 1.57 ft from static measurements. The groundwater being pumped still contained 5 percent product. The rate of product pumping was increased to 0.84 gph (20.3 gpd) to impose a gradient at the well to calculate a sustainable yield. The product depleted to 1.64 ft in 1 hour and the rate was subsequently decreased to 0.32 gph (7.6 gpd). The well was able to sustain this rate with 1.28 ft of DNAPL for the remainder of the test (0.5 hour). At the end of the test, the water was clear and the product was pure.

DUAL PUMPING TEST — EW-9

Date of test: 3/18/93

Start time: 09:57
Finish Time: 16:50

Time	Event	Comment
09:57	Static conditions	DNAPL thickness = 2.35
10:00	Begin pumping water	0.60 gpm (864 gpd)
11:45	Continue pumping water	DNAPL thickness = 2.42
13:24	Begin DNAPL pumping	DNAPL thickness = 2.42
13:38	Product = 90% water	DNAPL thickness = 1.85 Rate = 0.48 gph (11.4 gpd)
14:11	Status	DNAPL thickness = 1.54 Rate = 0.19 gph (4.6 gpd) Groundwater removal = 0.70 gpm (1,008 gpd)
14:45	All pumps shut off for 5-minute equipment check	No recovery
14:55	Decrease pumping rate	DNAPL thickness = 1.06
15:15	Check rate	No product recovered
15:20	Check rate; increase pressure	DNAPL thickness = 1.02; no product recovery
15:45	Continue to increase pressure	DNAPL thickness = 0.70; no product recovery
15:50	Check rate	100% product extracted @ 0.67 gph (16 gpd)
16:14	Status	DNAPL thickness = 0.27
16:25	Check rate	100% product extracted @ 0.58 gph (14 gpd)
16:50	Shut down pumping End test	DNAPL purged; thickness = 0.00 Total DNAPL removed = 1.5 gal Total groundwater removed = 250 gal

Note: Thicknesses reported in ft
DNAPL - dense nonaqueous-phase liquid
gpd - gallons per day
gph - gallons per hour
gpm - gallons per minute

Summary: Groundwater was pumped from the well (at 0.60 gpm) for 1.25 hrs before an increase in DNAPL thickness occurred. Maximum upwelling of 0.07 ft occurred prior to DNAPL extraction and could not be sustained during product removal (average 0.5 gph or 12 gpd).

DUAL PUMPING TEST — MW-7s

Date of test: 3/25/93

Start time: 09:45
Finish time: 16:00

Time	Event	Comments
09:45	Static conditions Begin pumping water	Depth to groundwater = 21.74 DNAPL thickness = 3.03 Water pumped @ 0.5 gpm (12 gpd)
09:55	Upwelling	DNAPL thickness = 3.10
10:00	Begin DNAPL extraction	DNAPL @ 0.32 gph (7.6 gpd)
10:20	Monitor	DNAPL thickness = 2.82
10:45	Monitor	DNAPL thickness = 2.17
11:00	Decrease rate	DNAPL thickness = 1.68 DNAPL @ 0.08 gpd (1.9 gpd)
12:00	Shut off product pump	DNAPL thickness = 0.52
14:05	Resume pumping product	DNAPL thickness = 0.64 DNAPL @ 0.13 gph (3.2 gpd)
15:40	End product extraction	DNAPL thickness = 0.00
16:00	End test	DNAPL thickness = 0.00 Total DNAPL removed = 0.62 gal Total water removed = 165 gal

Note: Thicknesses reported in ft
DNAPL - dense nonaqueous-phase liquid
gpd - gal per day
gph - gal per hour
gpm - gal per minute

Summary: Minimal upwelling was induced by removing water during the first 1.25 hours of the test. DNAPL yield could not be sustained during this test. Once DNAPL was depleted, it could not recover.

DUAL PUMPING TEST — MW-20i

Date of test: 3/9/93

Start time: 08:30
Finish time: 17:00

Time	Event	Comments
08:30	Static conditions	Depth to water = 28.43 DNAPL thickness = 18.25
08:45	Begin DNAPL extraction	DNAPL @ 1.45 gph (35 gpd)
10:00	Begin dual pumping	DNAPL thickness = 10.9; 1.8 gal removed Groundwater @ 0.5 gpm (720 gpd)
10:20	Upwelling of DNAPL	DNAPL thickness = 23.50; upwelling steady
11:00	Maximum upwelling	DNAPL thickness = 23.53 (steady)
12:15	Increase DNAPL rate	DNAPL removed = 5 gal; water removed = 70 gal Rate = 4.7 gph (114 gpd)
13:30	Removed DNAPL End DNAPL extraction Continue groundwater pumping	DNAPL thickness = 0.00 Stringers occur, but no consistently measurable quantity of DNAPL
16:30	Monitor	No upwelling; water @ 0.32 gpm (461 gpd)
17:00	End test	DNAPL thickness = 0.00 Total DNAPL removed = 12 gal Total groundwater removed = 165 gal

Note: Thicknesses reported in ft
DNAPL - dense nonaqueous-phase liquid
gpd - gal per day
gpm - gal per minute

Summary: Upwelling was induced in the well only during the period of well bore storage. Once 12 gal of product were purged, DNAPL did not accumulate in the well. The DNAPL recovered during this test represents 3 gal in the original well bore plus additional storage in the sand pack. It does not appear that dual pumping at the maximum rate of 0.53 gpm of groundwater can cause a substantial increase in DNAPL yields. Presently, this well can sustain pumping DNAPL at a rate of approximately 1 gpd.

DUAL PUMPING TEST — MW-22

Date of test:3/17/93

Start time: 09:40
Finish time: 15:40

09:40	Static conditions	Depth to water = 25.79 DNAPL thickness = 1.18
09:55	Begin pumping water	0.5 gpm (720 gpd); water clear
10:00	Upwelling of DNAPL	DNAPL thickness = 1.30 (upwelling of 0.12 ft)
11:35	Increase rate of water	Water @ 1.0 gpm (1,440 gpd); clear DNAPL thickness steady @ 1.30
13:30	Monitor; water rate increased	Water @ 1.5 gpm (2,160 gpd) DNAPL thickness steady @ 1.30
13:50	Begin pumping DNAPL Decreased water rate	DNAPL thickness = 1.25 Water @ 1.2 gpm (1,728 gpd)
14:10	Increase DNAPL rate	DNAPL thickness = 0.43
14:15	Monitor	DNAPL thickness = 0.39
14:27	Monitor	DNAPL thickness = 0.24
14:30	All DNAPL removed; stop DNAPL pumping	DNAPL thickness = 0.00 Rate: 2,250 mL/min (14.6 gpd)
14:35	Continue pumping water	Water @ 1.3 gpm (1,872 gpd)
15:15	Continue pumping water	Water @ 1.4 gpm (2,016 gpd); no DNAPL
15:30	Continue pumping water	Water @ 1.1 gpm (1,584 gpd); no DNAPL
15:40	End test	DNAPL thickness = 0 Total water removed: 360 gal Total DNAPL removed: 0.5 gal

Note: Thicknesses reported in ft
DNAPL - dense nonaqueous-phase liquid
gpd - gal per day
gpm - gal per minute

Summary: Minimal upwelling (0.12 ft) of DNAPL occured within the first 5 minutes of pumping of groundwater. This level was maintained for nearly 4 hours when DNAPL pumping was started. The DNAPL was quickly depleted and no sustainable level or rate of DNAPL was attained during this test.

DUAL PUMPING TEST — MW-D

Date of test: 3/24/93

Start time: 10:00
Finish time: 16:11

Time	Event	Comments
10:00	Static conditions Begin pumping groundwater	Depth to groundwater = 24.95 DNAPL thickness = 4.61 Pump water @ 0.40 gpm (576 gpd) Groundwater clear
11:00	Upwelling	DNAPL thickness = 5.07 (upwelling = 0.46 ft)
11:28	Maximum upwelling	DNAPL thickness = 5.50 (upwelling = 0.89 ft)
11:30	Begin DNAPL extraction	Groundwater dissolved product (not distinct phase) DNAPL being pumped contains 95% water
12:20	Monitor	DNAPL thickness = 5.21; water detected below DNAPL layer
12:30	Monitor	DNAPL rate @ 0.32 gph (7.6 gpd)
12:35	Monitor	Groundwater clear DNAPL rate unchanged
14:00	Monitor	DNAPL thickness = 2.75 Water detected below DNAPL layer Product pumped is 99% water
15:00	End DNAPL extraction	DNAPL thickness = 2.10 Water detected below DNAPL layer Product pumped is 99% water Last hour pumped @ 0.87 gph (20.9 gpd)
16:11	End groundwater pumping End of test	DNAPL thickness = 0.09 Total DNAPL removed = 1.5 gal Total water removed = 165 gal

Note: Thicknesses reported in ft
DNAPL - dense nonaqueous-phase liquid
gpd - gal per day
gph - gal per hour
gpm - gal per minute

Summary: Although up to 5.5 ft of DNAPL was measured in the well at maximum upwelling, this appears to have been a thick layer of product within the water column. Groundwater was detected beneath this discrete layer. MW-D could not sustain DNAPL extraction during this test.

TOTAL FLUIDS PUMPING TEST — EW-1

Date of test: 3/16/93

Start time: 10:00
Finish time: 14:10

Time	Event	Comments
10:00	Static conditions	Depth to groundwater = 25.0 DNAPL thickness = 0.26
10:00	Purge DNAPL	DNAPL thickness = 0.00
10:02	Begin pumping	2 gpm
10:20	Monitor total fluids	Clear
10:25	Monitor DNAPL level	No product
11:15	Monitor DNAPL level Upwelling of DNAPL	Thickness fluctuating 0.47 to 0.21, then not detected
11:20	Monitor total fluids	Brown/dirty liquid; 1% DNAPL
11:40	Monitor DNAPL level	No product
13:10	Monitor total fluids	3% DNAPL in water as separate phase
13:35	Monitor DNAPL level Upwelling of DNAPL	Depth to groundwater = 26.45 DNAPL thickness = 0.76
14:10	Pump failure; end test	Electrical short Total fluids removed = 505 gal Total DNAPL = 4.5 gal as 1–3% in water

Note: DNAPL - dense nonaqueous-phase liquid
gpm - gal per minute

Summary: Prior to beginning the test all free product was removed from the well. Minimal DNAPL upwelling occurred during the test. At 2 gpm, approximately 1–3 percent of DNAPL in water was removed during the test.

TOTAL FLUIDS PUMPING TEST — EW-4

Date of test: 3/23/93

Start time: 10:30
Finish time: 17:05

Time	Event	Comments
10:30	Static conditions; begin pumping	Depth to water = 24.14 DNAPL thickness = 1.36 Pumping rate = 2 gpm; 10% NAPL in water
15:45	Increase rate	4 gpm; total fluids = 620 gal; 10% NAPL in water Depth to water = 27.19
16:20	Monitor	Pumping @ 4 gpm; 5% NAPL in water
16:25	Increase rate	6 gpm
17:05	End test	Depth to water = 30.02 Total fluids removed = 1,020 gal Total DNAPL removed = approx. 82 gal as <5% to 10% in water

Note: Thicknesses reported in ft
DNAPL - dense nonaqueous-phase liquid
gpm - gal per minute
NAPL - nonaqueous-phase liquid

Summary: Total fluids were purged at three pumping rates. The percentage of NAPL in water was 3–5 percent for rates of 2, 4, and 6 gpm. Upwelling of DNAPL was not detected during this test.

BAILDOWN TEST — EW-10

Date of test: 3/19/93

Start time: 10:27
Finish time: 14:05

Time	Event	Comments
10:27	River level	23.40 ft below dock
11:08	Static well measurements	Depth to water = 16.48 LNAPL = thickness 1.25
11:24	Begin bailing LNAPL	
11:34	Stop bailing LNAPL; Monitor LNAPL recovery	Depth to water = 15.28 LNAPL thickness = 0.0
12:05	Monitor recovery	Depth to water = 12.30 LNAPL thickness = 0.05
12:13	River level	23.53 ft below dock
12:20	Monitor recovery	Depth to water = 15.70 LNAPL thickness = 0.45
12:34	Monitor recovery	Depth to water = 17.52 LNAPL thickness = 2.30
14:00	River level	23.10 ft below dock
14:05	Monitor recovery	Depth to water = 16.20 LNAPL thickness = 1.20 Total LNAPL removed = 2 gal

Note: Thicknesses reported in ft
DNAPL - dense nonaqueous-phase liquid
LNAPL - light nonaqueous-phase liquid

Summary: River levels and groundwater levels were taken over a period prior to beginning the baildown test to investigate the relationship of tides on LNAPL thickness in EW-10. Attached is a graph indicating the effects of changing river levels (tidal effects) and changes in stage due to precipitation) on groundwater levels and LNAPL thickness in EW-10.

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ATTACHMENT B

CREOSOTE EXTRACTION SUMMARY – MAY 1994

INTRODUCTION

This report summarizes the results of creosote extraction activities for May 1994 at the McCormick & Baxter Creosoting Company (McCormick & Baxter) site. Data are summarized for the month and for cumulative-to-date nonaqueous-phase liquid (NAPL) extracted and stored onsite. Other related activities associated with system maintenance, NAPL disposal, and general operations such as security and storm water collection are included.

DATA SUMMARY

Table 1 presents a summary of cumulative NAPL extracted since 1989, NAPL extracted by the automated system since February 1993, and NAPL extracted in May 1994. Table 2 presents NAPL extraction data from individual wells (including those located in TFAB trench) for May 1994 and the current status of water and NAPL in the two creosote collection tanks. Figure 1 is a site map indicating the locations of all site wells. Figure 2 presents a graphic summary of product extracted monthly during operation of the automated extraction system (February 1993 to present) and includes NAPL extracted from the interceptor trenches. Figure 3 presents the cumulative NAPL extracted from the site since 1989.

Periodic purging of selected wells in the tank farm area (TFA) and former waste disposal area (FWDA) resulted in recovery of approximately 34 gal of NAPL. Most of the NAPL was recovered from MW-20i (13 gal) in the FWDA and EW-18 (6 gal) in the TFA. No NAPL was recovered from wells in other areas. A significant portion of total NAPL extracted in May was light nonaqueous-phase liquid (LNAPL) (11 gal), the majority of which was contributed by EW-18 (7 gal) and EW-15 (4 gal).

LNAPL appears to be entering the trench wells but the quantity is still too small to measure. LNAPL is expected to accumulate in the trench as it migrates toward the river from the TFA. Extraction efforts are expected to be more effective during low river stage when groundwater gradients are steepest.

TABLE 1. NAPL EXTRACTION SUMMARY

	Total NAPL Extracted (gal)		
Area	Cumulative (since 1989)	Extraction System (since February 1993)	Current Month (May 1994)
TFA	863	201	10
FWDA	1023	447	24
TFAB Trench	0	N/A	0
Other Areas	10	8	0
Total Site	1,896	656	34
Total LNAPL	NA	NA	11
Total DNAPL	NA	NA	23

Note: FWDA - former waste disposal area
TFA - tank farm area
TFAB - tank farm area beach
N/A - not applicable
NA - not available

NAPL EXTRACTION SYSTEM MAINTENANCE

Routine maintenance activities included inspection of the air compressors, air lines, pressure vessels, pumps, discharge tubing, pump controllers, and creosote storage and containment systems. The air compressors were checked and condensate was drained from the tanks weekly.

The containments were routinely inspected and water was drained daily during periods of high rainfall. No sheen or oil were present on water in the containment areas.

SITE SECURITY AND SAFETY

One break-in occurred in May; however, no damage to the site was found. The vandals entered the site by cutting the barbed wire in the FWDA. PTI will continue to use the "buddy" system while conducting activities where exposure to hazardous materials is of concern (e.g., extracting NAPL). Special precautions to look for trespassers will be taken when initially entering the site each day.

TABLE 2. MAY EXTRACTION RECORD
McCORMICK & BAXTER

Well ID	Total hrs Pumped[a]	Pumping Frequency	NAPL Removed (gal) Total	NAPL Removed (gal) Cumulative Since Feb 1993	TANK MEASUREMENTS LNAPL (gal)	TANK MEASUREMENTS DNAPL (gal)	TANK MEASUREMENTS Water (gal)
Tank Farm Area							
Collection Tank					<1	394	35
MW-Is		P1	1.5	86.8			
MW-Ps				0.0			
MW-7s				1.3			
MW-8i				0.0			
EW-1s		P1	1.3	75.2			
EW-3s				0.0			
EW-4s				5.0			
EW-5s				0.6			
EW-7s				1.8			
EW-8s				1.8			
EW-17				3.66			
EW-18		P3	6.7	24.29			
Total	0.0		9.5	200.5			
Tank Farm Area Beach Interceptor Trench							
TM-1				0			
TM-2				0			
TM-3				0			
TM-4				0			
TM-5				0			
Total	0		0	0			
Former Waste Disposal Area							
Collection Tank					<1	572	383
MW-Ds		P3	3.6	40.1			
MW-Es				0.0			
MW-Gs				0.5			
MW-18s				0.0			
MW-20i		P3	13.4	247.5			
MW-21s		P1	0.4	40.9			
EW-2s				0.6			
EW-6s			0.0	17.3			
EW-9s		P2	3.0	30.9			
EW-10s				41.5			
EW-13				0.0			
EW-14				0.0			
EW-15		P1	3.8	27.4			
EW-16				0.0			
Total	0		24.1	446.7			
Other Areas							
MW-10s				5.0			
EW-11				0.0			
EW-12				2.7			
MW-19s				0.0			
MW-22i				0.7			
Total	0		0.0	8.4			
Site Totals			33.6	655.6	<1	965	418

Note: C – pumped continuously for number of hours reported
DNAPL – dense nonaqueous-phase liquid
LNAPL – light nonaqueous-phase liquid
P – pumped intermittently for number of purges indicated

[a] Total time extraction system was on

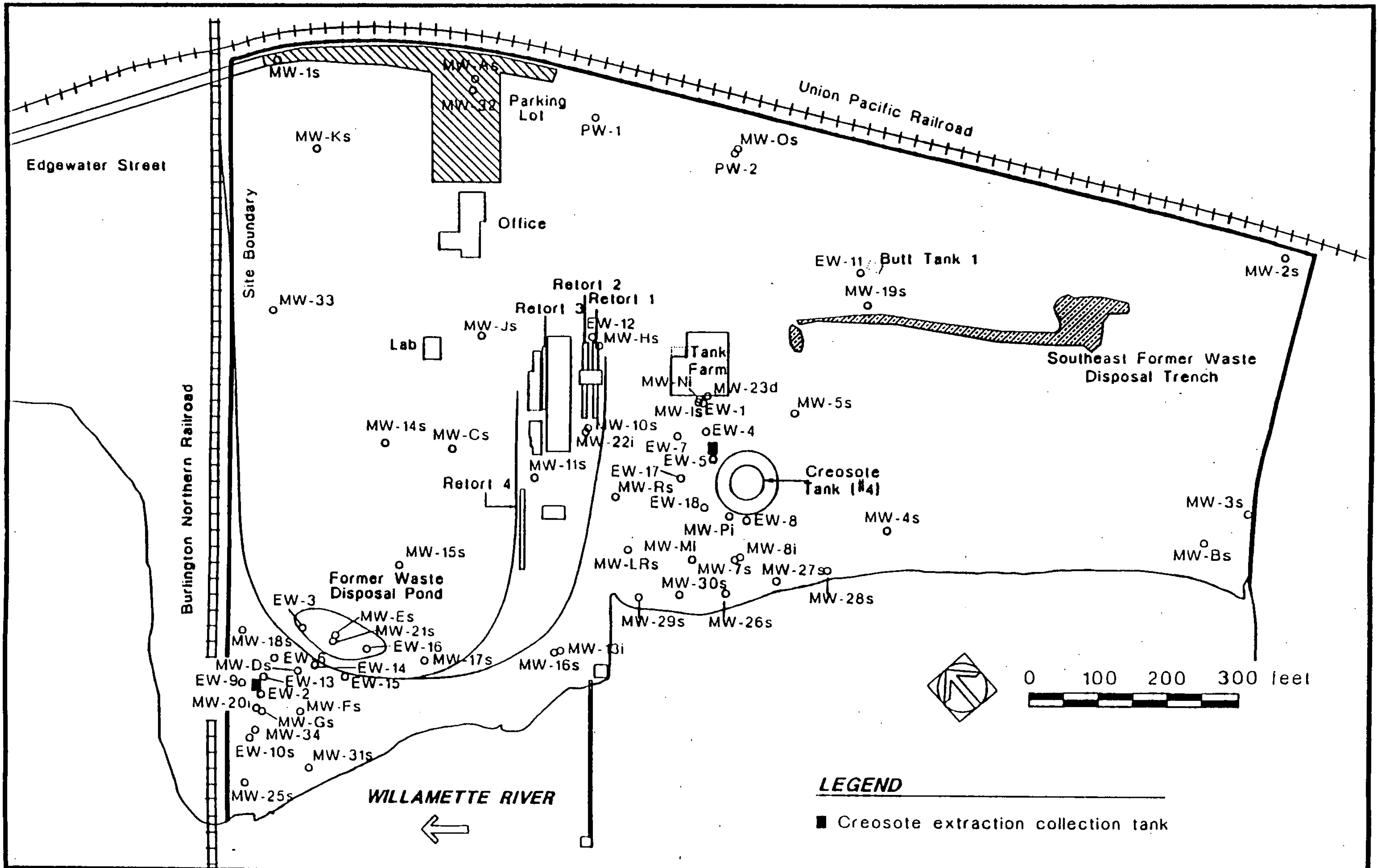

Figure 1. Site features and well locations.

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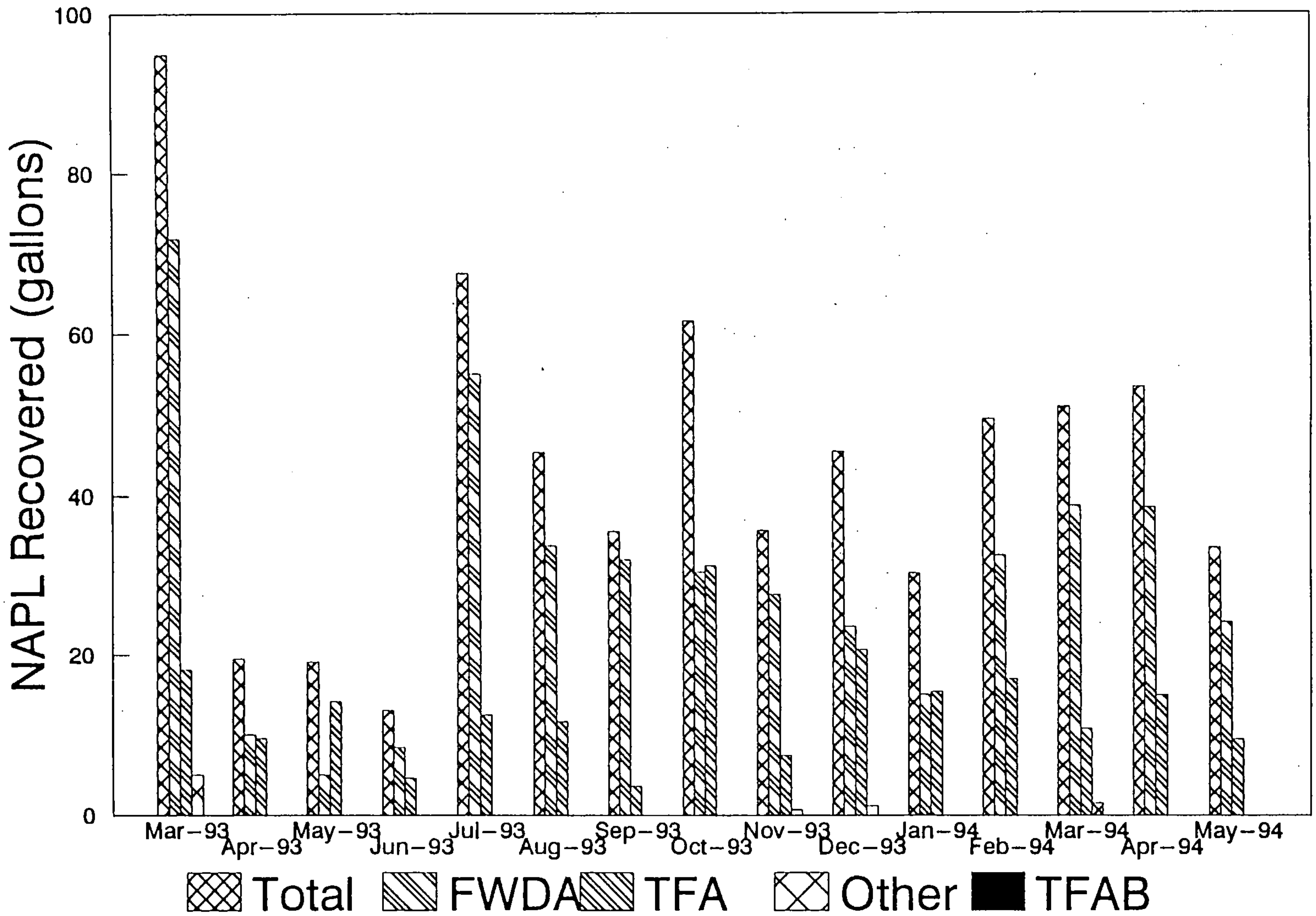
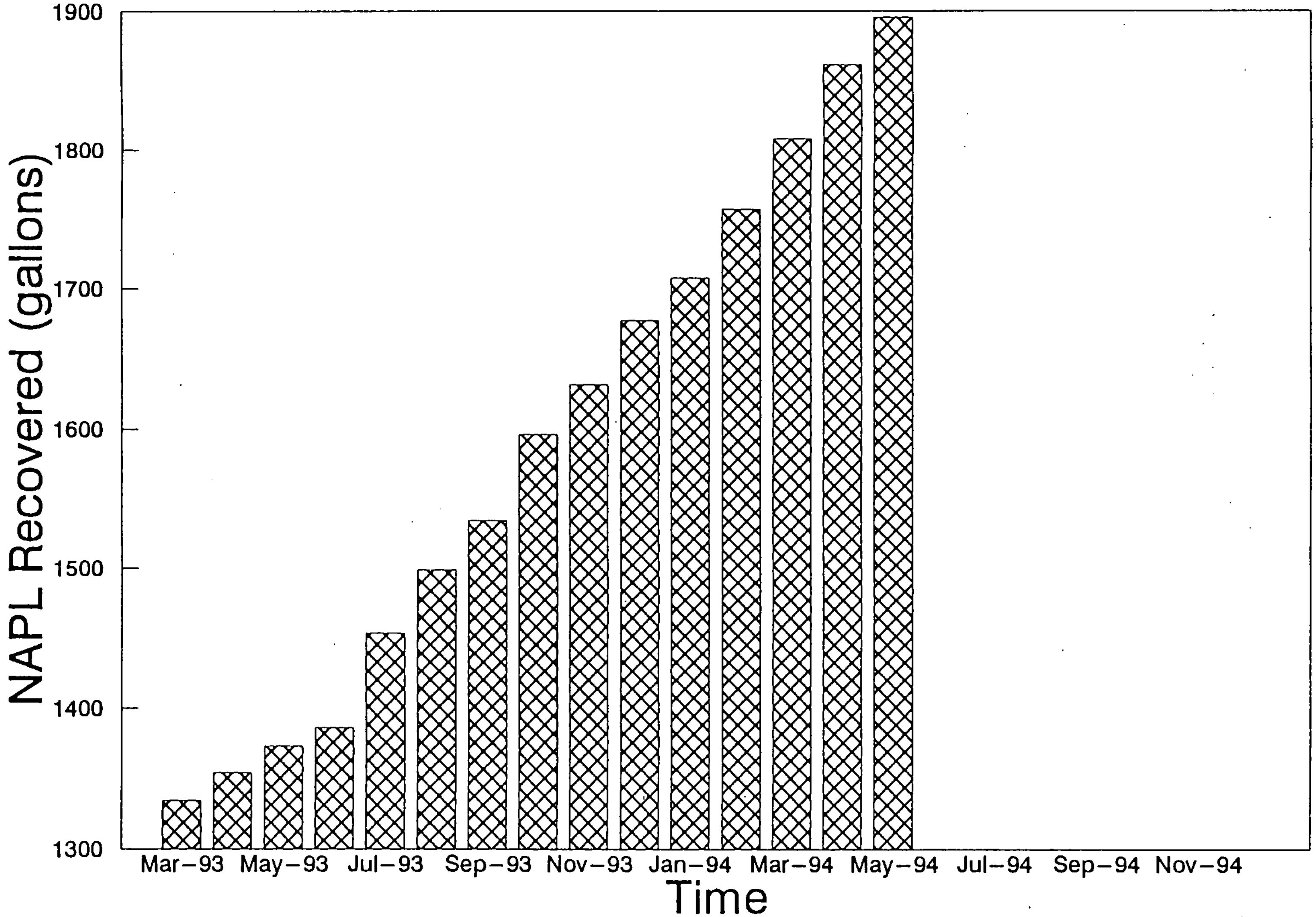


March 1993 includes data since start up (2/1/93)

Figure 2. Automatic NAPL extraction system recovery.

C4120304 EXTSUM.WK3 L 0494



1,240 gallons were extracted prior to implementaion of extraction system.

Figure 3. Cumulative NAPL extraction.

C4120304 EXTSUM.WK3 L 0494

NAPL DISPOSAL

Creosote continues to be collected and stored in the two creosote collection tanks. No water is being pumped or added to the collection tanks during creosote extraction.

STORM WATER COLLECTION SYSTEM

The storm water collection system has been shut down due to the start-up of Tank #4 storm water treatment. Table 3 lists the tank capacities and current tank measurements prior to water treatment.

TABLE 3. SITE STORAGE TANK MEASUREMENTS

Tank	Water Volume	NAPL Volume	Total Tank Volume	Unused Storage
TFA product collection tank	35	395	1,700	1,270
FWDA product collection tank	383	572	2,900	1,945
Tank #4	373,982	NM	743,000	369,018
Tank #9	650	4,000	41,000	36,350

Note: Results reported in gal
NM - not measurable